The Enhancement of Autonomous Marine Vehicle Testing in the South Florida Testing Facility Range

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LONG-TERM GOALS

The goal of this research project is to evaluate the performance of underwater marine vehicles by carrying out scientific experiments at the NSWC South Florida Testing Facility (SFTF) Range. Central to this theme is the characterization of the influence of physical, acoustic, biological and geological processes in the ocean on operational aspects of Autonomous Underwater Vehicles (AUVs). These vehicles are a new and important technology for the Navy because they provide the ability to survey shallow water regions in a systematic manner, using a number of small, inexpensive, unmanned vehicles.

A key aspect of the effort is the integration of AUV technology with other observing techniques to study various properties of the coastal ocean. The SFTF range is an excellent location for this purpose because it provides a domain rich in oceanic variability, a domain that is therefore adequate to assess a wide range of environmental conditions on AUV operations.

OBJECTIVES

The South Florida Ocean Measurement Center (SFOMC) partnership involves the Naval Surface Warfare Center Carderock Division (NSWCCD), Florida Atlantic University (FAU), University of South Florida (USF), University of Miami Rosensteil School of Marine and Atmospheric Science (UM-RSMAS), Nova Southeastern University Oceanographic Center (NSUOC), the National Oceanic and Atmospheric Administration-Atlantic Oceanographic and Meteorological Laboratory (NOAA-AOML) and The Harbor Branch Oceanographic Institution (HOBI). This Center was established for collaborative research efforts in ocean engineering and oceanography in South Florida and to provide the scientific community with a natural ocean laboratory within the existing SFTF range operated by NSWCCD.

APPROACH

Six scientific experiments were carried out in the SFTF Range in FY 1999. To achieve the scientific goals of these experiments the existing infrastructure at the range was enhanced with the specific objective of providing a calibrated site for oceanographic and engineering studies for underwater marine vehicles. The central theme of the oceanographic experiments was to understand and calibrate the underwater environment with respect to the physics, acoustics, geology, and biology of the range.

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As part of these studies extensive oceanographic measurement equipment was installed enabling long term observations that did and will support these and future experiments. A central theme in the engineering studies is to improve the understanding of AUV performance capabilities. These studies included the development of a permanent AUV underwater docking facility so that multiple AUV sampling schemes can be carried out. This will enable AUVs to operate over extended periods and, in the longer term, provide a facility for ongoing AUV research.

The scientific objectives of the six experiments were:

1. To characterize the remote sampling performance of AUVs and sensor systems for coastal mine reconnaissance and surveillance tasks; and to evaluate the impact of the environment on navigation, communications, and object detection/classification sensors.

2. To evaluate the reliability of deploying and operating AUVs in stormy weather and high sea states including the quantification of the effects on AUV navigation, communication and control performances. In addition extensive data sets will be collected on the environmental properties of the shallow water column during high sea states, including the effect of reverberation on the acoustic sensors.

3. To investigate the performance of AUV-based sensor systems combined with surface radar systems for mapping the subsurface submesocale dynamics associated with small-scale eddies and internal waves on the shelf circulation influenced by tides, low-frequency flows, current, and surface winds, and the net impact of these processes on AUV performance and acoustic propagation.

4. To provide a detailed description of the physical-oceanographic variability that takes place within the SFTF Range on time scales from hourly to seasonal, and to identify the processes that cause this variability.

5. To quantify range-dependent variations in bathymetry and inhomogenous bottom properties and variability in the sound speed profiles induced by internal waves on long-range transmission of sound in the littoral ocean.

6. To conduct a baseline survey of the biological, ecological and geological environmental conditions of the SFTF to optimize sampling by the AUV and other sensors, coupled with preliminary evaluation of direct AUV biological assessment.

WORK COMPLETED

The six experiments were carried out with significant effort and to a high degree of success, demonstrating the versatility of mobile AUV platforms for carrying out Mine Counter Measure (MCM) missions and for coastal oceanography. The experience gained during the MCM experiment will help to establish procedures for post processing data and determining environmental conditions. The Adverse Weather and 4-D Current experiments demonstrated how AUV-based measurements can be used in conjunction with ship-based and fixed measurements to characterize complex physical processes in a shallow water environment. The 3-D environmental array is in place and together with the Ocean Surface Current Radar (OSCR) formed the basis of the fixed measurement system on the

range. Significant data have been collected during the experiments and are currently being analyzed. The analysis will form the basis of long-term studies of air-sea interaction and of the impact of the Florida Current meanders on the coastal environment. The acoustic transceivers are in place and are expected to be utilized extensively during the next phase for determining acoustic propagation characteristics in a complex environment. Bio/Geological surveys of the range focused on determining the biodiversity of the in-water laboratory and it is expected to examine the seasonal variations during the next phase.

Improvements to the SFTF infrastructure accomplished to support these experiments included:

1. Development of an AUV and sensor support station and multiplexer (MUX) hard wired to shore.

2. Deployment of multiple permanent environmental monitoring arrays.

3. Improvements to an existing offshore node in 200 meters of water to support acoustic experiments.

The shallow water MUX was designed, fabricated and installed on the range and provided power and shore-based communication link to the instruments during the summer experiments. The design and preliminary tests have been completed in the development of the Docking Station and further work is expected during the next phase. The 200m node was refurbished and re-installed to interface with three new acoustic receiving arrays.

Successes were realized throughout the planning, construction, installation and experimentation phases. Some problems were encountered [2], however, most were overcome and did not significantly impact the results. An overview of what was conducted and a significant amount of preliminary data is presented in the final technical report [2]. Independent reports for each experiment will be published in appropriate journals as analysis is completed.

RESULTS

At an SFOMC Workshop held in February 1999, international participants from the ocean community pointed out the strategic importance of the SFTF range for oceanographic and ocean engineering studies related to the Gulf Stream and air-sea interactions. The participants recognized the wealth of talent and expertise within the center and the synergy among its scientists and engineers. Much interest was shown in the efforts that are already underway in establishing SFOMC as a center for continuous ocean observation and as an in-water laboratory in the 21st century. The achievements within the past year, including the completion of six major experimental efforts, related to MCM operations, physical oceanography, ocean acoustics and bio/geological assessments, reiterates the commitments of the partners in developing a center of excellence.

The centerpiece of the in-water laboratory at the SFTF range is a shallow water MUX which provides power to the various instruments and relays data in real time to shore via a fiber-optic communication. The MUX was designed, fabricated and installed on the range. It provides power and shore-based communication link to the instruments during the experiments.
The experiments carried out in the SFTF range addressed issues of importance to scientific and engineering aspects of AUV development as well as enhancements of the infrastructure in the SFTF

range. Capabilities for autonomous ocean sampling technology involving AUVs and oceanographic sensors have been demonstrated.

The MCM Experiment demonstrated the versatility of AUVs fitted with side-scan sonars in detecting buried objects. Significant experience has been gained from the experiment and will be utilized to make refinements in identifying targets. The experiment was also useful in establishing procedures for environmental assessment and for post processing information.

In the Adverse Weather Experiment, a successful, well-coordinated effort was able to capture a cold front event during Fall, 1998. The effort demonstrated the nature of process-oriented experiments that are possible at SFOMC and how AUVs can be utilized for profiling, and making *in-situ* CTD and small-scale turbulence measurements. Measurements using a 5-head ADCP, CTD casts from the support ship and the atmospheric data from the local C-MAN buoys provided the background information necessary to put the small-scale measurements in their proper context. Detailed analysis of the data is underway and will address issues relating to the energy budgets in the physical processes in a shallow water environment.

The ambient noise sonar, the PEACOCK, demonstrated the ability to operate and collect data ambient noise over a 24 hour period. Analysis of the noise data is in progress to identify the various major sources of noise that have been detected on the range. The work will help in assessing the noise environment on the range.

The design and preliminary tests have been completed in the development of the Docking Station. The SBL system has performed well, and the simulation work is ongoing to model and optimize this system. A docking station, when completed will be of immense importance in operating during storms.

Two underwater acoustic modems, Mills-Cross and General Purpose Modem, designed and built for acoustic communication during the development of the Docking Station, have been successfully tested at sea. The modems will be attached to the MUX.

The 4-D current experiment during summer 1999, demonstrated, for the first time, the relative importance of conducting AUV and ship-based sampling grids within a very high-resolution grid of surface current measurements from OSCR. Detailed analysis of current and turbulence measurements will provide new insights into complex physical processes occurring in a coastal ocean forced by a meandering Florida Current where maximum surface velocities exceeded 2 m/s. Furthermore, the observations significantly challenge numerical models of coastal circulation.

The 3-D Environmental Array is now in place and continuously collected current, salinity, temperature, density and wave data over the range during the 4-D Current Experiment and beyond. Data was also collected during Hurricane Floyd and will be of significant importance. Detailed analysis of the data will be carried out during the next year and will provide important characterization of the SFTF range. In the long run, the gathered information will be valuable in studying the impact of the Florida Current meanders on coastal processes, for example.
During the year, the design, fabrication and installation of the receiver arrays for the Acoustic Propagation Study (Experiment 5) were completed and model acoustic propagation results, for

planning the experiments, have been obtained. An environmental impact study including a Finding of No Siginficant Impact (FONSI) has been completed and approved by NAVSEA.

A number of Bio/Geological Surveys have been completed to characterize the biodiversity of the in-water laboratory. The surveys suggest that there are differences in the total number of fish as well as the total number of species between the three reef tracts within the SFOMC range. More data is required to confirm this and to determine seasonal variations. A detailed bathymetric survey of the range will be completed by NAVOCEANO in the coming year.

A number of enhancements and further collaborative adverse weather experiments are expected next year. At the February workshop, participants suggested visitor programs be set up, whereby scientists from other laboratories could come to SFOMC for studying pertinent processes on a range equipped with the instruments installed in this phase of the project. Further, a new initiative has been proposed to form a consortium of East Coast Observatories, involving WHOI, LEO-15, Duck, SABSOON and SFOMC. Such a consortium would co-ordinate efforts to monitor synoptic scale events as well share ideas and resources.

IMPACT/APPLICATIONS

These studies are of importance to the Navy because they improve the understanding of AUV mounted sensor system performance for shallow water mine hunting and surveillance tasks, assess AUV performance as oceanographic sensor platforms in adverse weather, and demonstrate the use of AUVs when integrated with other ocean sensor systems. In addition, the project has improved the understanding of the physical and biological oceanography in shallow water environments and has demonstrated how AUVs can be used to improve environmental monitoring. The physical oceanographic measurements also provided important information on how AUV shallow water mine hunting and surveillance programs can be optimized by taking into consideration the environmental conditions in the area of interest.

REFERENCES / PUBLICATIONS

[1] *Proceedings of the SFOMC Workshop, February 24 - 26, 1999*. Manhar Dhanak, Norman Caplan and Stanley Dunn, eds. Available online at: www.sfomc.org/Workshop99/index.html. Sponsored by NSF

[2] *Final Technical Report for the Enhancement of Autonomous Marine Vehicle Testing in the South Florida Testing Facility Range*. South Florida Ocean Measurement Center. September 1999.